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Kenneth F. Higgins
US Fish and Wildlife Service, kenneth.higgins@sdstate.edu

Michael A. Johnson
US Fish and Wildlife Service

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Kenneth F. Higgins and Michael A. Johnson
U.S. Fish and Wildlife Service
Northern Prairie Wildlife Research Center
Jamestown, North Dakota 58401

In a recent study of nonhunting mortality of wild waterfowl, Stout and Cornwell (1976) identified weather as one of the more significant causal agents. This paper describes an occurrence of spectacular avian mortality caused by a severe thunderstorm in North Dakota on 8 September 1977.

The storm was associated with a low pressure system in South Dakota. It developed about Noon CST north of Dickinson, traveled eastward and generally north of highway I-94, and continued into Minnesota at about 5:00 p.m. CST. The system moved at about 60 mph (97 km/h) over a 300 mile (483 km) stretch of the state; the width of the more severe portion of the disturbance was about 10 miles (16 km). The calculated ground area within the severe portion of the storm was 3,000 square miles (7,770 km²).

This storm hit Chase Lake National Wildlife Refuge (NWR) with winds up to 90 mph (145 km/h) and with hail stones varying up to golf ball size (D. E. Stoltz, National Weather Service, Bismarck, N.D., pers. comm.).

On September 10, R. E. Sabinash, a rancher north of Chase Lake NWR, reported dead and crippled sandhill cranes in a field near the refuge boundary. On September 11, L. M. Kirsch, M. A. Johnson, and D. J. Johnson investigated this report and picked up 9 dead cranes and 4 cripples, which later died (L. M. Kirsch, pers. comm.). In response to the Sabinash report, refuge managers J. R. Foster and R. A. Gilbert made a reconnaissance flight over parts of the storm area in eastern Kidder and western Stutsman counties where sandhill cranes and white pelicans are common at this time of year. They spotted more than 100 dead pelicans on Chase Lake NWR and about 40 on the Pipestem Reservoir near Jamestown; both areas apparently had been hit by the severe portion of the storm.

EFFECTS ON VEGETATION

Leaves and small twigs were beaten off cottonwood trees (*Populus deltoides*) at Chase Lake. Wolfberry (*Symphoricarpos occidentalis*) and silverberry (*Elaeagnus argentea*) were also pruned of small limbs and leaves and the bark was beaten off in spots. All small to medium height grasses and forbs were beaten down and gave the appearance of having been cut by a dull scythe. The residual ground litter was reduced to a coarse pulp and bare soil was commonly visible throughout the area.

The dominant vegetation on both islands in Chase Lake is marsh-elder (*Iva xanthifolia*) which often attains a height of 10 to 12 feet (3-4 m). Lamb's quarters

(*Chenopodium album*) was heavily mixed with the marsh-elder, forming very dense stands. As with the shrubs, these species were well stripped of leaves and branches, and large chunks were knocked out of the stems (Fig. 1).

FIGURE 1. Hail-damaged stems of marsh-elder plants on the big island at Chase Lake NWR.

INCIDENCE OF MORTALITY

Because Chase Lake has a large nesting colony of white pelicans (Sloan 1973), it was possible that some or all of the dead pelicans could have been young-of-the-year that had succumbed to starvation or other fates (Johnson 1976). We made an intensive ground search for storm-killed fauna on the north end of Chase Lake NWR on September 16. We searched about 1,500 m of the northwest shoreline, the two islands, a sand bar, the peninsula, and about 2,000 m of shoreline adjacent to the south end of the peninsula. Our tally was 226 dead birds, including the 13 reported by L. M. Kirsch, and 7 crippled pelicans (Table 1); we counted only storm-killed birds. Among twelve species represented, the greatest species loss was 151 white pelicans, 35 of which had U.S. Fish & Wildlife Service leg bands. Of the 151 dead pelicans, 142 were fledged young representing almost 6 percent of the 1977 chick population (Lingle 1977), which reflects a high post-fledging mortality.

The abruptness and deadliness of the storm was evidenced by the distribution of the dead birds (Fig. 2). Most of the pelicans were lying on the east side of the shoreline vegetation, leeward from the wind, and not far from the water's edge. Apparently these birds were killed instantly on the ground or in early, low flight. If they had been in higher flight such a wind would have carried them out into the

TABLE 1. Avian mortality due to a hail storm, Chase Lake NWR, 8 September 1977.

Species	Total	Big Island	Little Island	Peninsula	Shore Line	Sand Bar
White Pelican (*Pelecanus erythrorhynchos*)	151	75	45(7)[1]	31	—	—
Gadwall (*Anas strepera*)	2	—	—	2	—	—
Am. Wigeon (*A. americana*)	4	—	1	3	—	—
Green-winged Teal (*A. crecca*)	1	—	—	1	—	—
Blue-winged Teal (*A. discors*)	12	1	3	6	2	—
N. Shoveler (*A. clypeata*)	17	1	3	12	—	1
Sandhill Crane (*Grus canadensis*)	14[2]	1	—	—	13	—
Sandpiper (*Calidris* spp.)	5	—	1	2	2	—
Am. Avocet (*Recurvirostra americana*)	1	—	—	1	—	—
Gull (*Larus* spp.)	8	6	1	1	—	—
Short-eared Owl (*Asio flammeus*)	1	—	—	—	1	—
Barn Swallow (*Hirundo rustica*)	10	—	—	4	6	—

[1]An additional 7 cripples.
[2]This includes the 13 reported by L. M. Kirsch.

FIGURE 2. Hail-killed white pelicans on the big island at Chase Lake NWR.

water. Nearly all of the ducks were found along the shoreline, apparently drifted in by waves.

Many of the birds were apparently killed by hailstone blows to the head, neck, or back region. Very few of the birds had managed to reach the cover after being struck with hailstones (Fig. 2). Several of the cranes and pelicans had broken leg and wing bones. Some had more than one appendage broken.

As late as 25 September, crippled pelicans were seen wandering overland at Medina, 10 miles (16 km) southeast of Chase Lake. If these birds were storm victims, they survived possible starvation and predation for at least 17 days after the storm.

AGE AND SEX DISTRIBUTION

The distribution of adults to immatures and males to females when identification was possible is shown in Table 2. Of the dead pelicans and gulls, 94 and 73 percent, respectively, were immatures, whereas for ducks, the percentages were higher in adults and males. The noticeable difference in proportions of age between the dead pelicans and gulls and the dead ducks is most probably related to their reproductive status while at Chase Lake. Hundreds of pelicans and gulls annually nest and rear young on the islands in Chase Lake, whereas considerably fewer ducks use the islands for nesting and the lake for rearing young because the water is highly saline. In addition, the land around Chase Lake does not support a very good complex of wetlands, making the whole site a low production area for

ducks. We have no plausible explanation for the higher male:female ratio among the lead ducks (Table 2).

TABLE 2. Age and sex of hail-killed birds at Chase Lake NWR, 8 September 1977.

Species	Age		Sex	
	Ad.	Im.	M	F
White Pelican[1]	9	142	—	—
Gull[1]	1	6	—	—
Sandhill Crane[1]	—	1	—	—
N. Shoveler	14	5	15	4
Blue-winged Teal	5	5	7	3
Am. Wigeon	4	—	3	1
Green-winged Teal	—	1	1	—
Gadwall	1	1	2	0
TOTAL	34	161	28	8

The sex of birds of these species was not determined because of their decimated condition and the lack of good external sex characteristics.

SIGNIFICANCE OF HAIL STORMS

We offer no estimates of the total wildlife mortality that may have happened during this thunderstorm. Avian mortality at Chase Lake was definitely significant. Other reports of mortality in this same storm included a killdeer (*Charadrius vociferus*) and a lesser yellowlegs (*Tringa flavipes*) at Spiritwood, N.D. (E.K. Fritzell pers. comm.), 40 white pelicans at the Pipestem Reservoir, Jamestown, N.D. (J.R. Foster pers. comm.), and 6 white pelicans, 1 mallard hen (*Anas platyrhynchos*), 1 American coot (*Fulica americana*), 1 great blue heron (*Ardea herodias*), 6 gray partridge (*Perdix perdix*), and 3 white-tailed jackrabbits (*Lepus townsendi*) (R. J. Martin, U.S. Corps of Eng., Jamestown, N.D., pers. comm.) near Jamestown. We suspect mortality to wildlife occurred along the full extent of this storm while in North Dakota.

Almost concurrent with the 8 September 1977 hail storm and high pelican attrition in North Dakota, Bremer (1977) reported that 91 of some 400 white pelicans were killed and several pelicans and gulls were left crippled by a brief hail storm on 6 September 1977 at Todd and Belle Lakes, McLeod County, Minnesota. Hailstones in this storm varied from golf ball to baseball size and the storm occurred at 6:30 a.m.

Avian mortality caused by hail and wind in severe thunderstorms appears to be a fairly common occurrence, especially in the north central prairie states. Hochbaum (1955:167) cites an article from the 23 April 1954 Milwaukee Journal that describes the deaths of whistling swans (*Olor columbianus*), Canada geese (*Branta canadensis*), and ducks during an early April torrential rain and hail storm. Ordal (1964:98) reported that a severe hailstorm on 30 June 1958

destroyed much of the duck production in Otter Tail County, Minnesota. Smith and Webster (1955:374) and Smith (1960) describe two devastating hail storms in Alberta, Canada (14 July 1953 and 18 July 1953), that covered 960 square miles and killed between 64,120 and 148,630 waterfowl. They also described several aspects of the climatic conditions of hail storms in respect to avian losses. Fyfe (1957) presented photos from a similar Saskatchewan hail storm of 17 June 1957. On 5 October 1951, several species of birds and mammals were killed by hail and high winds during a severe storm in southwestern Oklahoma (Jones 1952). Stout and Cornwell (1976) found that hail was the most significant single factor in weather-caused deaths, and that mortality from weather was most prevalent in the Central Flyway and most of it was caused by hail.

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